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Abstract. This paper reports on an iterative design process for a serious game, which aims to raise situational awareness among different stakeholders in a logistics value chain by introducing multi-user role-playing games. It does so in several phases: After introducing the field of logistics as a problem domain for an educational challenge, it firstly describes the design of an educational board game for the field of disruption handling in logistics processes. Secondly, it describes how the board game can be realized in an open-source mobile serious games platform and identifies lessons learned based on advantages and issues found. Thirdly, it derives requirements for a re-design of the mobile game and finally draws conclusions.

Keywords: mobile learning, game-based learning, multi-user games, logistics, multi-role game-design

1 Introduction

Decision-making in sociotechnical systems is complex and error-prone due to interdependencies of tasks, conflicting goals in distributed responsibilities and a lack of information among the various stakeholders involved in decision-making [1]. The active sharing of relevant situational information might help to improve shared situational awareness (SSA) among the stakeholders involved [2], which can lead to improved decision making processes within sociotechnical systems. Therefore, it is crucial to understand the role of communication among stakeholders [3].

The SALOMO[1] project aims to provide training solutions to create situational awareness [2] to cope with this situation and to highlight the importance of communication. As multi-stakeholder decision situations confronted with time restrictions and incomplete information such as emergencies have been recognised as a relevant field

[1] SALOMO: Situational Awareness for LOgistic Multimodal Operations

Pre-print version. Please cite as:
Klemke, R., Kurapati, S., Lukosch, H., Specht, M. (2015). Lessons Learned from Creating a Mobile Version of an Educational Board Game to Increase Situational Awareness. In Conole, G., Klobučar, T., Rensing, C., Konert, J., Lavoué, E. (Eds.), Learning and Collaboration Technologies. Design for Teaching and Learning in a Networked World, Proceedings of the 10th European Conference on Technology Enhanced Learning, EC-TEL 2015, Toledo, Spain, September 15-18, 2015, Lecture Notes in Computer Science 9307 (pp. 183-196). Springer International Publishing. http://dx.doi.org/10.1007/978-3-319-24258-3

for training [4][5][6], a multi-user board game has been designed, which emulates the decision process in the port environment. The goal of the game is to sensitize stakeholders in a value chain about communication and inter-dependencies. The game was conceived to achieve a set of key objectives [7]:

- Understanding the impact of increased shared situational awareness (SSA) on individual, group and system level performance
- Setting a foundation to identify measures to increase SSA
- Offering a frame of reference to assess SSA in the organization and network
- Serving as a training tool for disruption management

The game focuses on how to handle disruptions in the transportation network, and whether and when to communicate information relating to the disturbance to other players. Several roles are played in the game; the vessel planner, the yard planner, the control tower, the resource planner and the sales department. Thus, the paper-based version of the game requires no more and no less than five players.

To improve the scalability of the board game, we aim to provide a computerized version of the board game, simplifying the game distribution and execution by providing an automated execution environment for locally distributed players.

While most game-based learning approaches focus on skill development and motivational aspects (see e.g. the meta-review in [8]), little work is reported on the aspect of shared-situational awareness in multi-stakeholder decision training (decision training itself is however covered e.g. in [9, 10]). With this work, we aim to provide new insights to this field of research, illustrated by an example in logistics. The main contribution of this paper is to reflect on a design process that started with a board game, which was transferred into a computerized mobile game and was redesigned into a new version according to lessons learned. While we do not report on a comparative study performed to assess the performance of each version, we rather give insights into design and application experiences as well as limitations of each approach.

In the remainder of this paper we give background information about the problem situation in logistics followed by an introduction of situational awareness in multi-stakeholder decision situations. We introduce and discuss our board game design as training game to increase situational awareness in a logistics decision situation and report on experiences made with this game. We continue describing the transfer of this game to a mobile serious game platform, and describe experiences made with the mobile game. From these experiences we derive requirements and design features for the second version of the mobile game. Finally, we draw conclusions.

2 Problem Situation in Logistics

In an international port, like the Port of Rotterdam, thousands of containers are moved every day in and out through different channels in container terminals [11]. A container terminal is the point of interaction between the different parties involved in container transportation [12]. Containers need to be moved as fast as possible to meet

the delivery time expectations of customers. Safety of the port and its operating personnel needs to be guaranteed at all times. To ensure the smooth operation of the port, different stakeholders, equipped with different responsibilities have to interoperate: *Control tower* ensures the overall smooth operation; *Resource planner* assigns the port personnel; *Yard planner* is responsible for the internal storage of containers in the port; *Vessel planner* is responsible to deliver containers to and from vessels; *Sales manager* is interested in customer satisfaction.

Unplanned and unanticipated events affecting the normal flow of goods and operations in supply and transport networks are termed as disruptions [13]. Disruptions have become common phenomena in port operations. The main categories are port accidents, port equipment failures, dangerous goods mishandling, port congestion, inadequacy of labour skills, hinterland inaccessibility, breach of security, and labour strikes [14]. Disruptions may cause severe ripple effects resulting in high costs and dire consequences on the wellbeing of the surrounding environment [15]. A machinery breakdown in the port may e.g. lead to a security risk, causing an area to be closed. This may delay the unloading of ships, which delays also their loading and planned departure, which also affects the trucks, etc. The operating individuals, mentioned above, need to take decisions to mitigate the disruptions together with external stakeholders. However, they are not always aware of these interdependencies and effects. Given the undesirable ripple effects of the disruptions in seaport operations, it can be deduced that the resilience of seaports, and their terminals, is essential for the resilience and robustness of transport networks as a whole.

As a first step to address this problem, this paper introduces a tabletop simulation game as an approach towards increasing situational awareness of planners and decision makers in seaport operations during disruption management to improve the resilience of seaport container terminals. In the following, we introduce how we conceptualize shared situational awareness and why it is so crucial in container transportation, before we illustrate how we translated this concept into a simulation board game.

3 Situational Awareness

Situational awareness (SA) is the broadly accepted definition describing the level of awareness that an individual has of a situation, an operator's dynamic understanding of 'what is going on', including the perception and comprehension of a situation and the prediction of its future state [16]. Much has been written about the construct, yet it remains profoundly contentious. Of the definitions and approaches available, Endsley's three level, information-processing-based model has received the most attention [16]. Due to the significant presence of teams in contemporary organizational systems, the construct of team SA is currently receiving increased attention from the human factors community [17]. Distributed teams comprise members interacting over time and space via technology-mediated communication [18]. Team performance itself comprises two components of behaviour, teamwork (team members working together) and task work (team members working individually). Shared situational awareness (SSA) is multi-dimensional, comprising individual team member SA,

shared SA between team members and also the combined SA of the whole team, the so-called 'common picture'. Add to this the various team processes involved (e.g. communication, coordination, collaboration, etc.) and the complexity of the construct quickly becomes apparent. Most attempts to understand team SA have centred on a 'shared understanding' of the same situation. Nofi, for example, defines team SA as: 'a shared awareness of a particular situation' [19] and Perla et al. suggest that 'when used in the sense of ''shared awareness of a situation'', shared SA implies that we all understand a given situation in the same way' [20]. In the following, we introduce a study in which we research in how far a simulation game session can support a group of players in developing SSA by providing different levels of communication and cooperation. The increased level of SSA should lead to improved resilience in container terminal operations.

4 Phase 1: Board Game Design

Simulation games can be defined as 'conscious endeavour to reproduce the central characteristics of a system in order to understand, experiment with and/or predict the behaviour of that system' [21]. It is a method in which human participants enact a specific role in a simulated environment [22]. In our case, we focus on the use of simulation games as a training tool, which is meant to improve communication between stakeholders, and to improve their SSA in seaport container terminals as an example of a complex system. For the conceptualization of our game, we follow a framework by Meijer [23], which is based on the work of Klabbers [24]. According to this, a simulation game is always designed with an objective (for learning purposes) or based on a research question (research purposes). The game consists of objectives, rules, roles, constraints, load and situation, which are defined by the game designer [23]. In our case the game follows predefined disruption processes within which players interact to take decisions. These decisions are scored and influence game parameters (such as performance, safety, and customer satisfaction).

Resilience is the ability for a system or organization to bounce back to normality when affected by a disruption [25]. For seaport container terminals, bouncing back to normal can be quantified in terms of the Key Performance Indicators (KPIs). The KPIs can be categorized as efficiency of operations and costs, safety, customer relationship, sustainability, strategic/competitive position in the market, profits and losses [26]. As the game only focuses on operations, the KPIs considered for the game are safety, efficiency of operations, and customer satisfaction. Based on literature and brainstorming sessions with professionals in the container terminal business, the challenges in disruption management in container terminal operations have been translated into contextualized game play. The development of the game took over 8 months, as it was an iterative process following design, evaluation and validation cycles.

The resulting disruption management game for intermodal transport operations in ports is a 5-player tabletop board game. The game is presented to the participants in the form of a game session (see Fig. 1). One game facilitator supports the game play. Every game session begins with a briefing lecture, introducing the concept and moti-

vation, rules, set-up and scoring of the game (see table 1). At the beginning, each player starts with a limited number of communication tokens.

The game play begins after the briefing session. Each level of the game play has five rounds. Within each round, each participant receives individual information, which may be incomplete, irritating, or misleading. Each player can spend one of his/her communication tokens to share information with other players. Consequently he/she has to take decisions on follow-up activities, which influence individual scores and group scores.

After every round, the individual and group scores are explained, when the game facilitator reads out the effects of the decisions made by the players on the KPIs. At the end of each level, an overview of the situation based on the participants' decisions is presented. For evaluation purposes, the game play is observed thoroughly by the game facilitator, while the decisions and scores are recorded.

Table 1. Input and Output elements in the disruption management game

Input/ Output	***Description in the game***
Roles	Vessel planner, Yard planner, Resource planner, Control tower manager, Sales
Rules	• There are individual game boards for each participant as well as an overall game board for the container terminal system with KPIs, contain varying information and rules based on the level of the game play • The KPIs are all maximum at the start of the game, they deteriorate after every round, and can be increased by mitigation actions of participants • Participants have information cards as well as action cards, the former used for communication, the latter for performing mitigation actions • Communication can be (virtually) done via e-mail, phone and conference, with differing effectiveness and costs. Limited tokens have to be used to communicate, showing communication costs (time and resources) • The information cards contain disruption details. After a round of information sharing, participants have to perform mitigation actions • Mitigation cards vary for each round. They contain 3 choices from which participants need to choose one mitigation action card • Based on the actions of the participants the game master changes the scores of the KPIs after every round
Objectives	*Overall:* To maintain resilient transport operations *Individual:* To maintain individual performance indicators as well as the overall KPI of the terminal
Constraints	Information availability, time, resources to communicate
Load	Different disruption situations, different levels of escalation of disruptions, varying channels and cost of communication and information sharing
Situation	University classrooms; Logistics, supply chain and transportation companies; Professional and knowledge institutes
Participants	Academic researchers, students and professionals in the transportation, logistics and supply chain industry

Qualitative data	Observations from the game session by the game master, report of decisions after every round
Quantitative data	Post-game survey

The game session concludes with a de-briefing session, where the game facilitator explains the principles of disruption management, the challenges faced by practitioners, the relationship of the game elements to the challenges, a review of the scores and the reasons for obtaining such scores, alternative strategies, comparison between scores of different play groups and the reasons for it. This session is mainly to provide a learning experience for the participants.

Fig. 1. The board game in action

After the de-briefing session the game facilitator encourages the participants to provide feedback about the game and their experience, which is recorded. After the game session, the participants fill in an online survey on the usefulness of the game.

5 Experience with the Board Game

The data gathered from the game and the survey is analysed qualitatively to gather insights into disruption management for resilient intermodal port operations. Several game sessions were conducted based on the above design, played with 10 researchers, 15 experts, and 80 graduate students in supply chain, logistics and transportation. The most important result that emerged was the clear difference in the behavioural patterns of players at different game levels. Based on their awareness of the disruption scenario, roles and objectives of others, there was a difference regarding relevant information sharing for mitigating the disruption.

In level 1 of the game play, all the players had limited awareness of the disruption scenario, the effects of their decisions and their objective in the game. In level 2, players made good use of the available communication channels, as they understood where to send and receive information. Several discussions and negotiations were made among the players during level 3. Players teamed up to jointly mitigate the situation. Sometimes, players sacrificed their individual KPIs to boost the overall KPIs. Well-informed decisions were made in level 3.

The results from the mentioned sessions create a helpful learning experience in the field of disruption management and resilience of container terminal operations. While these positive results motivate us to continue, we also observed and collected a number of reasons motivating the transfer of the board game to a mobile version:

- As the board game requires a human game facilitator to control the complex game processes, the mobile version should use automated processes.
- This automatisation should also simplify the game's distribution and scalability.
- Game results should be traceable for the necessary debriefing phase. While in the board game only the human memory is available for debriefing, the mobile version should track all user interactions and decisions.
- The board game requires all players to be present in a single room. While this fosters a common game experience, it imposes an unrealistic situation, as in reality the different persons would be distributed across the port.

In the following, we illustrate how the board-game concept has been translated into a mobile multi-player game, taking into account above-mentioned reasoning.

6 Phase 2: Transfer of the Board Game into a Mobile Game

Based on the board game described above, we designed a version for mobile devices using ARLearn. ARLearn is a platform for the flexible, pattern-based design of mobile process-based learning games [27, 28] comprising an authoring interface, which allows binding content items and task structures to locations, events, and roles and to use game-logic and dependencies to structure the game process. The platform has been recently used for several pilot studies in the cultural heritage domain [29], in security-related fields [30], and in health care related emergency training [31].

Related approaches comprise the ARIS platform [32], which offers the possibility to author location-based mobile games. While ARIS has been successfully used in several application examples [33], it does not support multi-player/multi-role games. QuestInSitu is a mobile learning platform which mainly focuses on assessment [34] in location-based contexts. Robles et al. [35] describe an implementation of a team-enabled mobile gaming platform. The location-based task model allows for linear games, where a new task description follows the previous one.

In the mobile version of the board game, the game facilitator is replaced with the automated ARLearn game logic. The game design follows the board game process as described in the section 'Board game design and experience'. Fig. 2 depicts one round in the game process. Each level consists of five rounds, which are synchronized after each decision. Each round gives access to a new situation description.

While level one of the game isolates the different players completely, subsequent levels give access to limited communicative resources. This shall foster the players to exchange information creating awareness for other player's situation and the overall consequences of own decisions (Fig. 2). Fig. 3 displays screenshots of the mobile SALOMO game showing communication messages and decision points. In this example, the player can choose between alternative actions, leading to different scores.

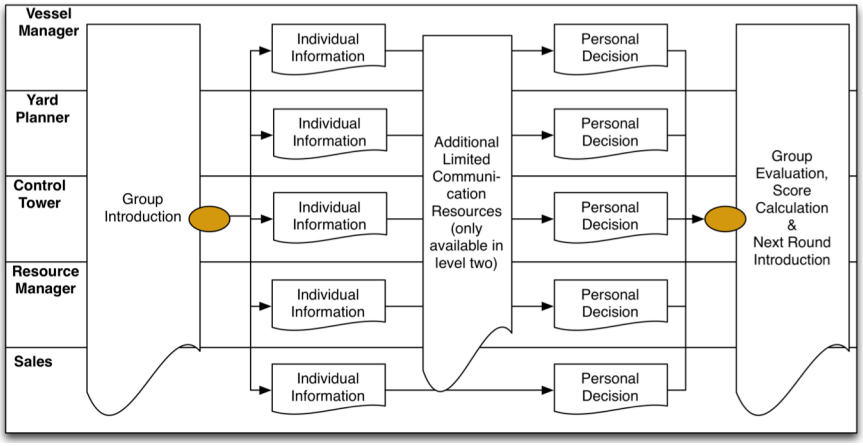

Fig. 2. One round of level one / level two with communication

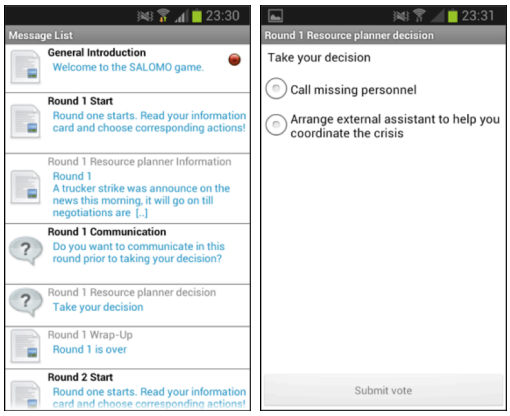

Fig. 3. Screenshots of the SALOMO game: message overview and decision point

7 Experiences with the Mobile Game

For the first version of the mobile game we collected feedback in internal playtests. Even though, we aimed to create the mobile version as close as possible to the board game, its playability differs in some aspects significantly from the board game:

- Five players can play the game in separate locations as their mobile devices are synchronised automatically via ARLearn. The ARLearn game engine automatically synchronizes the game state between the different players
- No human game facilitator is required, as the game engine automatically updates the game state, evaluates player decisions and distributes information. Game

rules, processes, decisions and all other game resources are encoded as game design script in ARLearn.

- The mobile devices provide a realistic situation scenario, as the players use communication means similar to their daily activities as the game interaction is based on mobile devices: users receive messages and interact with question items. Multimedia dialogue sequences complement the message driven approach to provide more immersive situations.
- Players don't need to be in one location but can be mobile. All communication and synchronisation tasks are performed via the ARLearn platform

The ARLearn platform supports the automatic logging of all player interactions. Through a web-based front-end this data can be retrieved and used for a debriefing session. While the logging data is available, the debriefing itself is not (yet) automatized and has to be performed together with a trained expert. While these differences represent improvements with respect to the applicability of the game, our internal playtests also revealed some drawbacks of the mobile version.

Player dependence: the game process is synchronized across the players. After a player took his/her decision in one round he/she has to wait until the other players also finished the round before the game continues. While this mechanism is copied from the board game, it leads to frustration in the mobile game as the players are not necessarily around one table. Consequently, they cannot observe the game process of the other players while waiting nor can they communicate with the others (and e.g. putting social pressure on them to speed up), which is possible in the board game.

Missing motivation for communication: players get access to a limited number of communication features in levels higher than level one. However, we observerd that players rather aim to keep their communication tokens instead of spending them. While this effect can also be observed in the board game, it is stronger in the mobile game, probably increased by the following issue.

Missing feedback for effects of decisions & communications: while the board game keeps all players around one table and thus allows a lot of informal or non-verbal communications among players, the mobile players are cut off this communication channel. Consequently, they can hardly judge in how far a specific communication message leads to an improved decision at the receiving player

No direct measurement of communication: one important aspect in the board game is, that players can observe other players' communicative behaviour and thus can adapt their own communicative behaviour. In the mobile version, players can only refer to that part of the communication that is directed towards them and thus miss a relevant part of ongoing communication

Complexity of the role definitions: five players in five roles with different involvements in the game appear to be too complex for the mobile game. Again, putting the players around one table, enabling their direct communication, and supporting them with a game facilitator simplifies this problem. Players can better feel the role dependencies in this situation. As the isolated players of the mobile version do not get this kind of direct feedback, it is harder to understand conflicts between the different roles and importance of each role.

8 Phase 3: Re-designing the Mobile Game

Based on the experiences drawn with the previous version of the mobile game, we redesigned the game process to deliver an updated version, which keeps the advantages of the mobile game but aims to eliminate its current drawbacks. Consequently, we still want the game to be playable by distributed players in different roles without a human game facilitator. Also, we do not want to change the realistic messaging-approach. However, we clearly aim to address the observed drawbacks.

Gain player independence: To get rid of annoying waiting times, we aim to get rid of the majority of synchronisation points in the game process. Instead, we want to allow each player to follow her game process independently. The different players shall still play connected in the way that they can exchange messages, but they can follow their individual decision paths without having to wait.

Clearly motivate communication: Instead of relying on a limited number of communication means, we aim to reward effective communication by giving positive score for important messages shared on time and by giving negative score for unimportant or late messages. As messages represent shared received information the importance of a message can be specified at design time.

Give feedback for effects of decisions & communications: Players sharing messages should receive feedback stating, if the message was received on time (i.e., before the receiving player took a corresponding decision). Also, negative feedback (e.g. late arrival or unnecessary information) should be given to the player. The feedback should be given in form of acknowledge message and will be auto generated.

Direct measurement of communication: While players should not be able to sneak into other players' messages, they should be aware of the amount of ongoing communication. This feature, which is not available in real life, could help the players to adapt their own communication strategy to the group level.

Simplify role definitions: We plan to reduce the number of roles playing the mobile game to three by combining two of the previously defined roles (control tower and resource planner) into the new controller role and by omitting the vessel planner role. Control tower and resource planner have a strong overlap and can be combined. The vessel planner only participates in the game play in a limited way and can thus be ignored. This way, the roles are better balanced (about equal effort for each role).

Fig. 4 displays one round of information, communication, and feedback in the redesigned game. The number of roles is reduced to three (*simplification of roles*). Each player receives information at slightly different points in time and needs to take an individual decision (*player independence*). Each player can also decide to inform other players about the information received and/or their decision taken. If their communication message arrives the other player in time and can influence their decision (see message from sales to yard planner as an example), they receive positive feedback (*motivation and feedback for communication*). If they communicate too late (see message from controller to yard planner as an example), they receive negative feedback (*feedback for communication*).

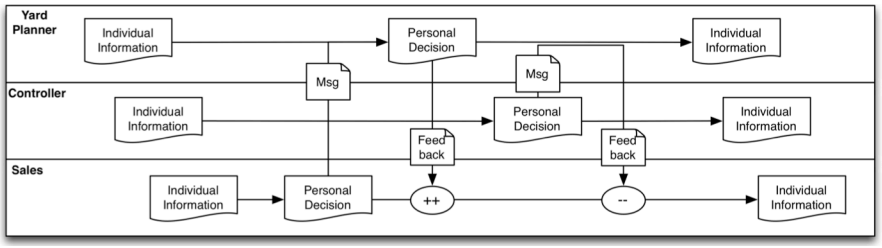

Fig. 4. One round of the redesigned mobile game

9 Conclusion

From disruption management processes observed at a large international port, we have designed a board game simulating these processes with a varying degree of communication means available to players. This board game has been successfully trialled with various user groups. Some difficulties of its game design are that it requires a skilled game facilitator to be available during game play, which leads to decreased scalability of the game. Furthermore, the board game requires all players to be within a single room, which is unrealistic for the stakeholders in a big port.

Consequently, we have chosen a multi-user, multi-role enabled mobile game environment (ARLearn), to create a computerized version of the game, which can be played by players in the different roles simultaneously. While the mobile version of the game could improve the identified weaknesses of the board game [36], we identified a number of new issues arising. These issues are mainly due to cutting off the informal communication among players by separating them.

The main contribution of this paper is to reflect on the design process, which transfers the board game into a mobile game, and to analyse the problems solved and the issues introduced during this process. Table 2 compares the transitions from the board game to the mobile game and the planned changes towards its second version along the dimensions execution, scalability, location independence, introduction & debriefing support, group experience, realism, player independence, motivation for communication, feedback, measurement of communication, and complexity of the roles.

We have learned, that transferring a board game to a mobile game by producing a close copy of the gameplay can lead to a completely new situation. The mobile game play comes along with changed communication behaviour and requires more explicit feedback mechanisms and stronger motivations to foster desired behaviour. We believe that our insights can be transferred to other fields of multi-stakeholder decision training situations by clearly separating formal and informal communication aspects and respecting them systematically within the game-design.

The work described here represents a starting point for the sound design and implementation of multi-user decision training games for various training scenarios. While we have first results indicating that this kind of games is helpful and can provide effects [37] in other case studies, we are looking for ways to further formalise the design and implementation of multi-user decision training games [38]. Our research

therefore follows two directions: firstly, the further development of our game scenarios and technical implementation focuses on enhancing the immersiveness of our games. Secondly, the further evaluation of training scenarios in various settings should deliver stronger evidence about their usefulness and about measurable effects.

Table 2. Transitions from the board game to two versions of the mobile game

Dimension	Board game → Mobile game (v1)	Mobile game (v1) → (v2)
Execution of game process	Human game facilitator no longer needed; scores and progress automatized.	(No change wrt. to v1)
Scalability	Game scalability increased.	(No change wrt. to v1)
Location independence	Location independence and mobility introduced but leads to isolation.	Isolation effect reduced bye better motivation for communication.
Introduction support	In-game tutorial and explanations replace costly introduction process.	(No change wrt. to v1)
Debriefing support	Debriefing activity supported through automated data collection.	(No change wrt. to v1)
Group experience	Informal communication between players cut-off	Group experience to be increased by better communication and feedback mechanisms.
Realism	More realism through isolation and message style communication. Player dependence limits realism.	Player independence shall increase realism.
Player independence	Turn-based board game process leads to player frustration in mobile game.	Gain player independence by introducing asynchronous game phases.
Motivation for communication	Due to missing motivation players do not consume their communication tokens	Rewards for effective communication shall foster communication among players.
Feedback	Lack of informal communication leads to loss of awareness	Explicit feedback about communication, decisions, and timing to raise awareness
Communication measure	Adjusting own behaviour by observing other players is hardened in the mobile version due to isolation	Indicators for own communication behaviour in relation to others' aim to grasp the own position in the network of players
Complexity of roles	The number of roles is perceived as being to complex for effective game play.	Number of roles shall be condensed for more effective game play.

Acknowledgements. The SALOMO project is funded by the Dutch Institute of Advanced Logistics (DINALOG).

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